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BIM and energy efficient retrofitting in school buildings

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Abstract

The aim of the research project presented in this paper is to experiment actions to improve the existing school building management and maintenance through a technological and process innovation based on the Building Information Modeling (BIM). In the field of refurbishment and reuse of existing buildings, some of the most sensible and specific sectors are investigated, particularly focusing on energy efficiency, structural improvement, up-to-date information on completed works and quality control. The project's goal is to take advantage of the information technologies, beginning from software interoperability, and defining a new working philosophy that should use the BIM also in the monitoring, managing and maintenance phases. This will result in an advanced drafting of the design standards for refurbishment/reuse of public buildings by a hierarchic data structure (Preliminary Requirements). The optimization of the process will lead to a complete building modeling (architecture, structure, facilities, deterioration) in order to describe both the residual building performance and the outgoings of the refurbishment design (Final BIM Requirements). The research has been validated by on-field application (school buildings).

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Keywords: BIM; schools; energy efficiency.

1. Introduction

The Building Information Modeling is a project management methodology that governs the materialization of the information system through the use of dedicated software.

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Applying of BIM methodology (see Fig. 1) to existing constructions does imply, first of all, a thorough study of the documentation and then an accurate analysis of the true state of the building. The mapping of residual performances provides the basis to proceed with the evaluations of the interventions in order to realign the building to the current rules and with the planning of its ordinary and extraordinary maintenance operations. In the building, the structural, architectural and system models allow for instance seismic-dynamic analysis, energy or noise analysis and encourage to design targeted interventions, very tailored to the weaknesses and the specific needs of each building element; the goal is to assess in advance the investment impact in terms of benefits, costs, implementation timing and payback time as well.

Only a really systematic workflow setup can result in a consistent, reliable and methodical filing of all the information scouted out from old and new archives and can prepare the correct and efficient archiving of future data. Furthermore, the cloud information management provides a simple but effective tool for on-site monitoring of all the maintenance operations. This is especially useful to create an integrated system for fault detection and intervention planning, when it comes to manage several properties.

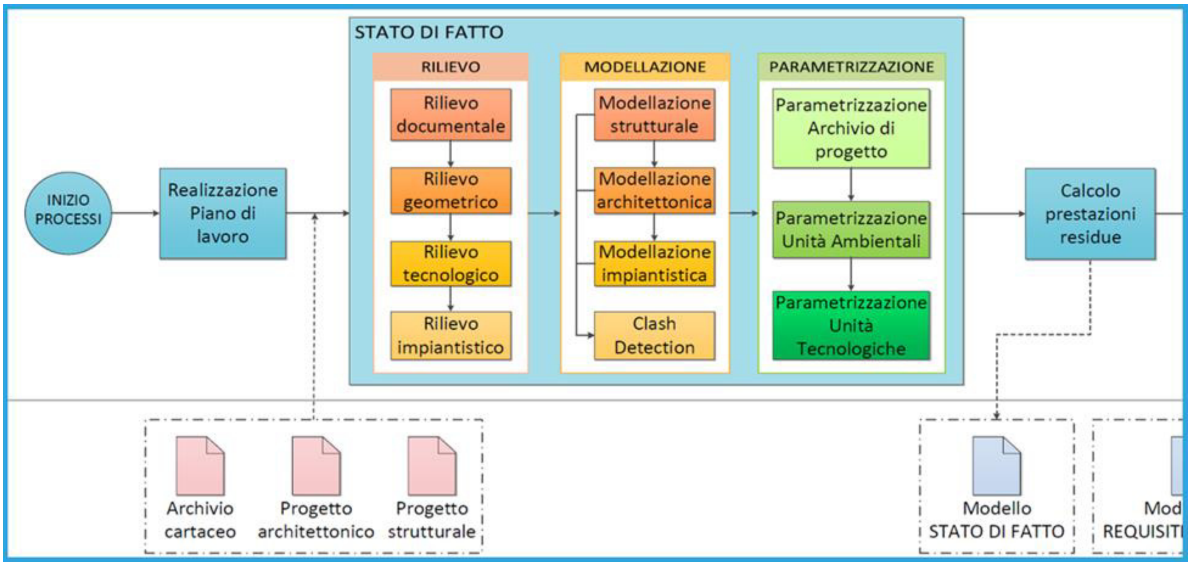

Fig. 1. Workflow (survey stage)

2. Work stages

The proposed work strategy on the existing school buildings applies the BIM methodologies to the survey of documentation, technology, structure and facilities to obtain a virtual synoptic table to base several design solutions. The accurate definition of the performance specifications should explicit the requirements both for the typological units and the building elements. By means of considering the intervention investment, its benefits in the future, the cost on the life cycle and so on (optioneering design), it can be defined, at a later time, any intervention strategies e. g. for energy efficiency and, if necessary, for regulation compliance.

In order to obtain the complete status of an existing building it is compulsory to know its history: this comes from drawing examination, design analysis, techniques and construction technologies investigation; but it is even more weighty the full knowledge of the interventions carried on the school over the years, for example to improve or restore the current performance of technical elements. All the information gathered during this cognitive process should be digitally stored to allow a fast and effective consultation: getting information from the same (and sole) database make possible a smart design process for every designer and a brighter coordination of the maintenances (Fig. 4).

The whole work strategy and software has been validated trough a full on-site testing, carried out on a secondary school in Melzo (Italy): it consists of a main two stories building and a gym block (Fig. 2). The school was constructed in the early Seventies using the current technologies at those times (reinforced concrete, brick walls, single glazed windows etc.): in the next future, it will be part of a refurbishment program carried on by the Melzo Municipality.

Fig. 2. “Mascagni” secondary school in Melzo

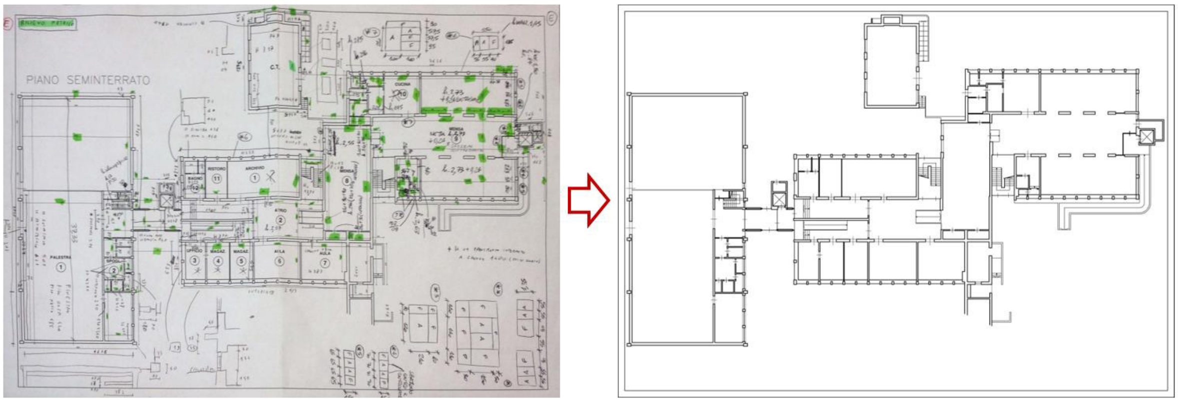

Fig. 3. Basement plan of the secondary school “Mascagni”: sketch mapping (left); plan restitution in the BIM model (right)

2.1. Documentary survey and filing model structure

The first phase of the work consists of inspecting, scanning and archiving all the information scouted on the papery files that have been collected by the owner year after year: design drawings, calculation reports, contracts, building work accountancy etc., including all certifications, authorizations and qualifications by the competent boards (e. g.: Health Board, Fire Prevention Agency, Monuments Bureau, Italian Olympic Games Committee, etc.).

An initial screening identified the sections and topics into which the digital archive should be organized. Depending on the amount and the peculiarities of the available documentation, each datum has been associated with the model part to whom it belongs, namely building elements, typological units or construction parts (Fig. 5). This first step of the work revealed to be very time consuming, but it has been considered by the research team as the main pillar on which all the BIM modeling work relies: without this it has been assumed it would be impossible to proceed in an orderly manner with all the following steps.

In parallel some inspections are conducted to determine whether there are critical situations (in case, previously complained), or to check the maintenances already carried out on the building (Fig. 3).

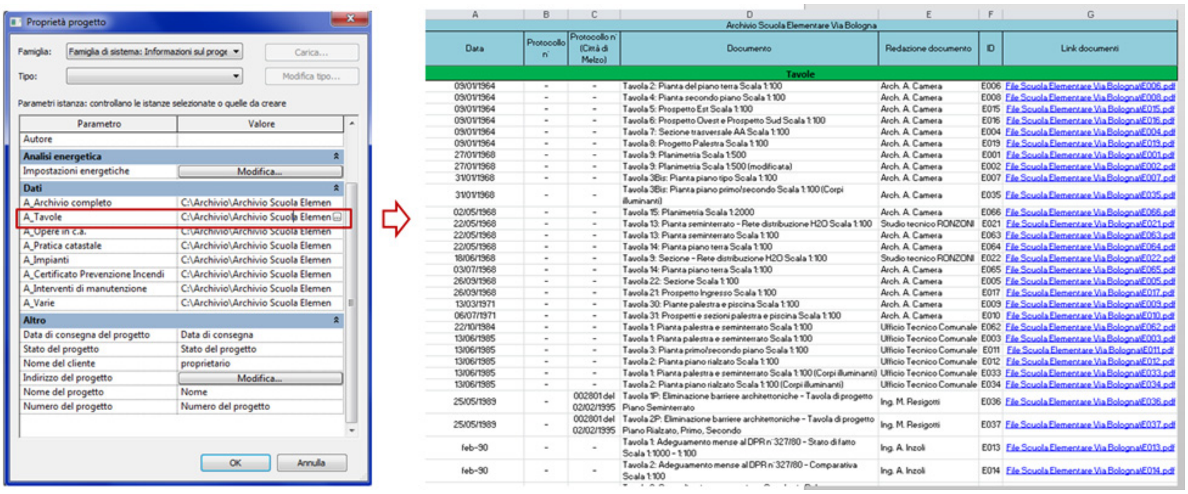

Fig. 4. Example of BIM Digital archive

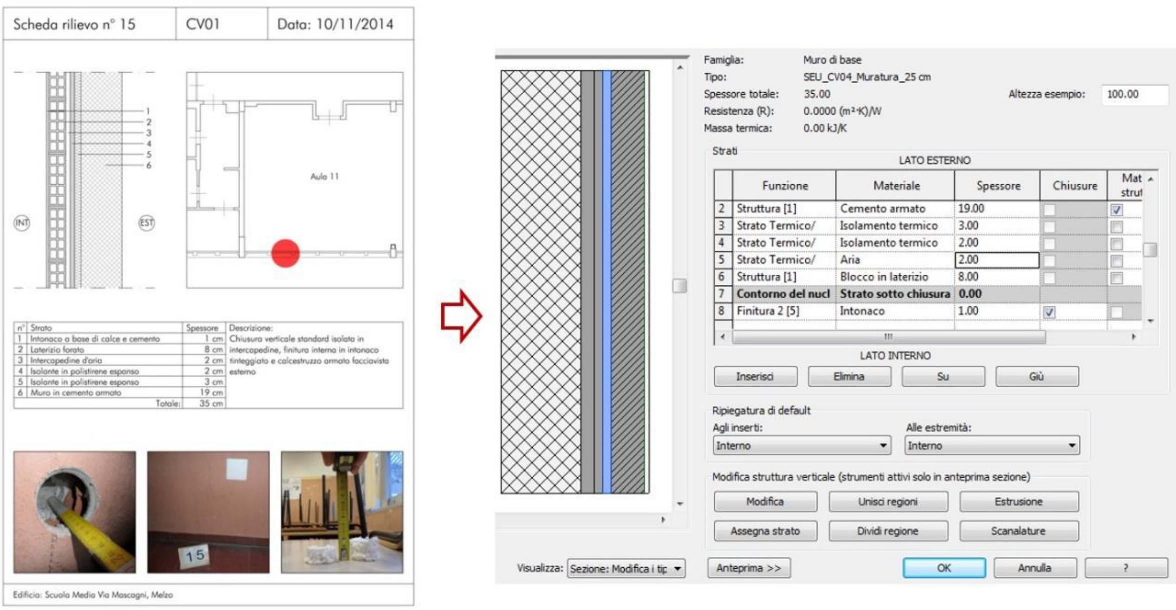

Fig. 5. Technological survey and layer consistence input in the BIM model

2.2. Architectural mapping; technological, strcutural and facility survey

While or after implementing the archive, a close survey of the building is carried out: it consists not only of a geometric mapping of each room, but also of a check if the room destination has been changed with respect to the original situation.

Besides, sample tests and investigations are carried out on the major building elements: this is very useful to have the evidence of the materials, thicknesses and building technologies really applied and thus to have a reliable technological survey of the whole edifice. Similarly, the specification mapping is implemented also on the plants, networks, facilities and control systems.

With relation to the Customer's specific needs, nondestructive structural tests and measurements can be completed in order to check the working status of the bearing components (pachometer testing, load testing etc.).

2.3. 3D model and information modeling

The second stage concerns the organization of all the collected information into a BIM three-dimensional model of the building (Fig. 6). Consequently the model becomes the "materialization" of all the technical information related to the element or system to which it refer.

Each element of the model is "informed" of all the parameters, specifications and characteristics of the real element. For instance, it can then be associated with the relevant technical data sheets, certificates and declaration of proper installation or everything else that could be useful to the current management and the future maintenance.

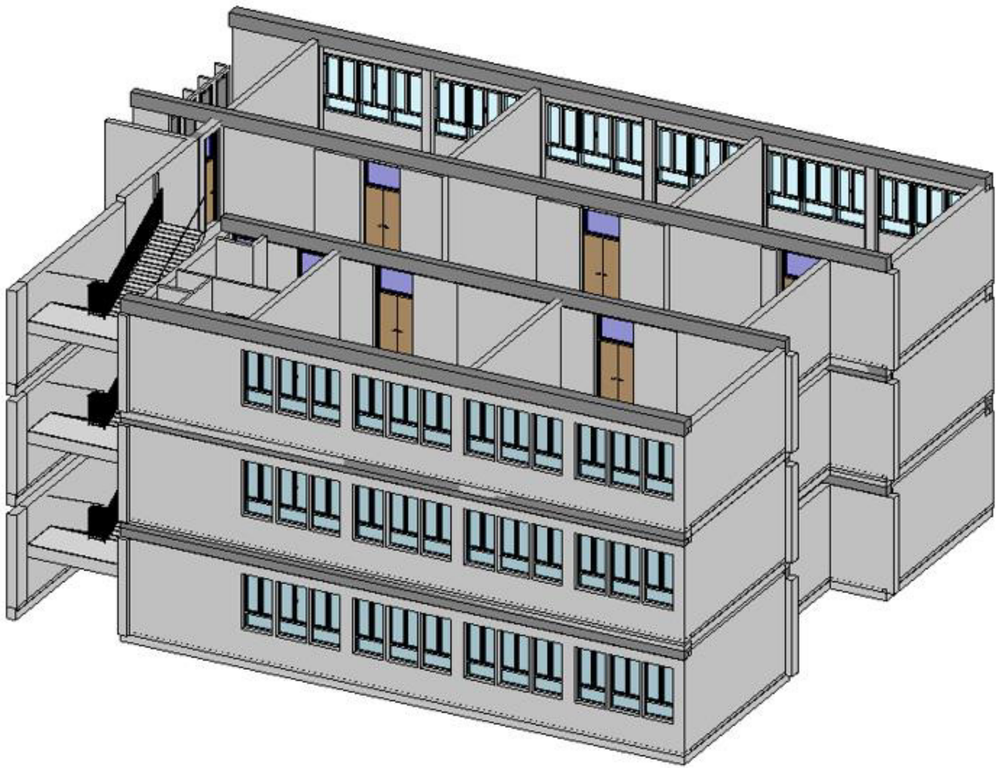

Fig. 6. BIM model of the school "Mascagni"

2.4. Residual performance evaluation

On the basis of the performed surveys and of the real state model it is possible to calculate or accurately estimate the main building residual performances, which can be referred to a single technical element (vertical envelope, window frame etc.) or to the building as a whole. The former group includes, for instance, the thermal transmittance (U-value) of the envelope, its thermal mass, its sound insulation properties etc.. The second group includes whole building performances as heat loss, acoustic reverberation time etc..

Assessing a residual performance is generally intended also to verify the Law compliance of the building, e. g. regarding escape routes, emergency stairs, disabled accessibility and so on.

This step completes the first part of the job, concerning the information on the knowledge status of the building.

2.5. Performance specifications draft

Following the full modeling of the building, the key output is to draft up a performance based tender (Fig. 7) to realign the building to the actual standards and regulations. Its requirements and performances will be the gap to fill. i. e. the goal of any maintenance or upgrading proposal.

RA 02

CONTROLLO DEL BENESSERE TERMICO INVERNALE

1. NORMATIVE DI RIFERIMENTO

- UNI EN ISO 7730:1997: *Ambienti termici moderati. Determinazione degli indici PMV e PPD e specifica delle condizioni di benessere termico;*
- UNI EN ISO 7726:2002: *Ergonomia degli ambienti termici – Strumenti per la misurazione delle grandezze fisiche.*
- D.Lgs. n. 192/05
- D.Lgs. n. 311/06
- D. n. 59/09
- D.Lgs. n. 56/10
- UNITS 11300:2008

2. CLASSI PRESTAZIONALI

TIPOLOGIA DI ATTIVITÀ PREVISTA	LIVELLI PRESTAZIONALI				CLASSE
	PPD* max [%]	Temperatura operante [°C]	Velocità aria [m/s]	Umidità relativa [%]	
Nessuna attività continuativa	15	19± 4	0,18	30-70	0
Transito, attività individuale e collettiva continuativa	10	22±2	0,18	30-70	1
Attività individuale continuativa (studio, ufficio, ecc)	6	22±1	0,15	40-60	2

3. METODI DI VERIFICA

PROGETTO (SPECIFICHE)	IN OPERA (PRESTAZIONI)
Verifica sul progetto delle condizioni termiche nelle condizioni: - Regime stazionario, in condizioni estreme di progetto - Regime dinamico, in condizioni di funzionamento intermittente dell'impianto di riscaldamento. NB: per l'applicazione del metodo di Fanger per la stima del Voto Medio Previsto e della Percentuale di Insoddisfatti si ipotizza un indice di vestiario peri a 0,5 clo.	Misura in opera delle condizioni termiche secondo UNI EN ISO 7726

U.A.09
AULA DIDATTICA LABORATORIO

Attività svolte	Utenti	Elenco locali	Sup m²
Didattica per la ricerca, le attività individuali o in piccoli gruppi	Insegnanti, studenti	PT_LAB. SCIENZE	50,00
		PT_LAB. INFO	50,00
		PT_LAB. LINGUE	52,00
		PT_LAB. IMMAGINE	52,00
		P1_LAB. MUSICA	53,00
	TOTALE	5	257,00

Requisiti specifici		Classe prestazionale	Rif. Scheda
BENESSERE	R.A. 01 - controllo benessere acustico	3	RA 01
	R.A. 02 - controllo benessere termico invernale	1	RA 02
	R.A. 03 - controllo benessere termico estivo	1	RA 03
	R.A. 04 - controllo qualità dell'aria	5	RA 04
	R.A. 05 - controllo benessere ottico luminoso	4	RA 05
	R.A. 06 - controllo benessere psicologico visivo	3	RA 06
SICUREZZA	R.A. 07 - controllo sicurezza al fuoco	1-2-1-0	RA 07
	R.A. 08 - controllo sicurezza elettrica	0	RA 08
	R.A. 09 - controllo sicurezza gas	0	RA 09
	R.A. 10 - controllo sicurezza sostanze tossiche	0	RA 10
	R.A. 11 - controllo sicurezza circolazione	0	RA 11
	R.A. 12 - controllo igiene	1	RA 12
	R.A. 13 - controllo antintrusione	0-3-1	RA 13
FRUIBILITA'	Dotazione elettrica	v. Tav IP 01/02/03	
	Dotazione informatica	v. Tav IP 01/02/03	
	Dotazione terminali per climatizzazione	v. Tav IP 04/05/06	
	Dotazione idricosanitaria	v. Tav IP 04/05/06	
GESTIONE	R.A. 14 - controllo consumo energetico	-	
ASPETTO	pavimento	di tipo resiliente, in teli a tinta unica	
	soffitto	in legno, ad elementi complanari a vista, colore chiaro	
	zoccolino	in legno coordinato ai coprifili delle porte	
	pareti cieche	di colore chiaro, lavabile	
	pareti trasparenti	vedi serramenti esterni	

Fig. 7. Form for performance specifications.

3. Conclusion

Applying the BIM methodology to existent constructions open a wide range of possibilities: the very innovation of the one here summarized is to embed the present situation, the maintenance history and the real performance of the case study school into a online 3D BIM model through a large survey campaign both in the edifice and in the owner's archives. The wished easy accessibility to this vast data system by all the operators (managers, designers, engineers, service men etc.) will lead to a strongly tailored list of possible maintenance or upgrading strategies, all cost optimized, regulation compliant and customer oriented.